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Instrumentation Facility for the Evaluation, Testing, and Packaging of Polymer Materials and Devices for Integrated Optical Circuits and Photonic Systems

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13. ABSTRACT (Maximum 200 words)
This report describes the instrumentation facilities now available for the evaluation of new polymer materials for photonics and the measurement of polymer photonic devices. This new instrumentation was purchased and constructed using the funds from this DURIP Grant. The new facilities include attenuated total reflection and ellipsometric instrumentation for the measurement of electro-optic coefficients. Instrumentation for the measurement of thin film waveguide loss and material index of refraction by spectroscopic ellipsometery are also available. The high speed characterization of polymer devices using pico-second pulses at a wavelength of 1550 nm are now possible with this instrumentation.

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FINAL REPORT

Instrumentation Facility for the Evaluation, Testing, and Packaging of Polymer Materials and Devices for Integrated Optical Circuits and Photonic Systems

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Polymers in Photonics

Polymer materials are expected to play several key roles in integrated optical circuits and systems. These materials can be used for low loss passive optical and infrared waveguides, electro-optic switches and high speed modulators, and integrated optical components such as wavelength filters, channel dropping filters, and power combiners.

Critical Instrumentation

We have established, using the funds from this DURIP grant, a laboratory to make custom measurements of the waveguide absorption loss and the electro-optic coefficients of candidate polymers, to do custom fiber packaging, and to make available a commercial wideband instrument for the measurement of indices of refraction. Sources are now available for each instrument to cover the important wavelengths from 780 nm to 1500 nm. This facility now makes available to the research community a complete set of measuring instruments with the necessary staff expertise in a single location. It also makes possible an interaction between scientists for comparing new materials.

Facilities Now Available

1. Instrumentation for Measuring Electro-optic Coefficients at the Application Wavelengths

A. <u>Attenuated Total Reflection</u> In this method light is prism coupled into a slab waveguide of the EO polymer and the typical dip in reflected power at the mode coupling angle is observed. The slight variation in the reflected power as an electric field is applied to the polymer is detected using signal lock-in detection techniques. The EO coefficient can be derived from this measurement and if higher order mode dips can be detected, a back-up measurement of film thickness and index can also be done. EO coefficients of less than 1 pm/V can be reliably measured. The measurements can be done at a variety of wavelengths of interest.

B. <u>Ellipsometric EO Instrument</u> In this approach, the state of polarization of the reflected wave from a polymer film is monitored and the variation in the polarization as an electric field is applied across the film gives a measurement of the EO coefficient. Lock-in detection is required and a measurement over a range of angles is required to understand the effects of the films adjacent to the polymer (metal films, substrate, and claddings). To achieve an accurate EO measurement requires a good understanding by the operator to sort out the possible effects of the various films. This instrument is used on materials in which waveguiding is not possible and is used as a second measurement to cross check with the easier ATR measurement. A wide range of wavelengths can be used and measurements of less than 1 pm/V are practical.

2. Instrumentation for Measuring Absorption Coefficients at the Application Wavelength.

Thin Film Waveguide Loss At the operating wavelengths, the upper limit on the acceptable losses in fabricated waveguides is 2-3 dB/cm. This is well below the sensitivity of an IR spectrophotometer for the films of 1-2 μm in thickness. Longer interaction lengths are required and therefore waveguiding in the films is required. This measurement approach uses prism coupling into a thin film waveguide mode; the waveguide is dipped into a high index liquid where the mode is out-coupled at the liquid - air interface. As the waveguide is dipped into the liquid, the out-coupled power is detected as a function of distance between the in-coupled point and the liquid interface. The accuracy of the measurement is 0.1 dB/cm and can be used over a wide range of wavelengths.

3. Instrumentation for Measuring Index of Refraction at the Applications Wavelengths.

Spectroscopic Ellipsometer - The index of refraction of the core and cladding materials must be known to the third decimal place and over a wide wavelength range in order to design integrated optical devices. Ellipsometry is the method of choice but standard instruments are extremely time consuming if measurements at several wavelengths are required. A new instrument is on the market which is automated to scan over angle to give high accuracy measurements at 44 wavelengths simultaneously. We have purchased a VASE Md. M-44 from J. A. Wollam Co., Inc., Lincoln, NE,

4. High Speed Optical Measurement Facilities.

To characterize the high speed polymer EO devices we have purchased instrumentation for pico-second pulse generation and amplification at a wavelength of 1.55 microns. This facility will allow the measurement of short pulse response and, by a correlation technique, the rf response out to several hundred GHz. The facilities work at the important telecommunication wavelength of 1.55 microns.

Source Sharing

It is important that each of the measuring instruments be capable of making measurements over a wide band of wavelengths. This is because the potential applications span a wide wavelength band and because an understanding of the materials requires measurements at several wavelengths. To give this wideband capability we has used a source sharing set-up which allows the three custom instrument to share the laser sources. This is the only practical way to keep the costs reasonable. The three instruments (the ATR set-up, the EO ellipsometer, and the waveguide loss measurements) are constructed on the same optical table. A fiber distribution system allows any one of the laser sources to be used in any one of the three instruments.

Recent Publication Made Possible by the New Facilities

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2. "Optimized oxygen plasma etching of polyurethane based electrooptic polymers for low loss optical waveguide fabrication", A. Chen, K. Kaviani, A. Remple, S. Kalluri, W. H. Steier, Y. Shi, Z. Liang, L. R. Dalton, Journal of the Electrochemical Society, **143**, 3648, Nov. 1996..

3. "Monolithic Integration of Waveguide Polymer Electrooptic Modulators on VLSI Circuitry", S. Kalluri, M. Ziari, A. Chen, V. Chuyanov, W. H. Steier, D. Chen, B. Jalali, H. Fetterman, and L. R. Dalton, Phot. Tech. Lett., Vol.8, May, 1996.

4. "1,3-Bis(dicyanamethylene) Indane Based Second Harmonic Order NLO Materials", S. Sun, C. Zhang, L. R. Dalton, S. M. Garner, A. Chen, W. H. Steier, Chemistry of Materials, **8**, 2539-2541, (1996

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6. "Progress Towards Device-Quality Second-Order NLO Materials: 1. Influence of Composition and Processing Conditions of Chromophore-Containing Polyurethane Networks on Nonlinearity, Temporal Stability, and Optical Loss", S. S. H. Mao, Y. Ra, L. Guo, C. Zhang, L. R. Dalton, A. Chen, SA. Garner, W. H. Steier, Chemistry of Materials, V 10, 146-155 (1998).

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8. "Translating microscopic optical nonlinearity to macroscopic optical nonlinearity: The role of chromophore-chromophore electrostatic interactions" A. Harper, M. He, F. Wang, J. Chen, J. Zhu, S. Sun , L. R. Dalton, A. Chen, S. Garner, A. Yacoubian, W. H. Steier, D. Chen, H, R, Fetterman, J. Optical Society Amer., B, 15, 329-337, (1998)

9. "Low $V\pi$ electro-optic modulator using a high $\mu\beta$ chromophore and a constant bias field" Antao Chen, Vadim Chuyanov, Hua Zhang, Sean Garner, and William H. Steier, Jinghong Chen, Jingsong Zhu, Mingqian He, Shane S. H. Mao, Aaron Harper, and Larry R. Dalton, Optics Lett, 23, 478-480, March 15 (1998)

11. "Integrated optical vertical polarization splitters using polymers", S. Garner, V. Chuyanov, A. Chen, S-S Lee, W. H. Steier, L. R. Dalton, Proceedings of SPIE, Vol. 3278 (1998)

12. "Progress towards the translation of large microscopic nonlinearities into large macroscopic nonlinearities in high $\mu\beta$ materials", J. Zhu, M. He, A, Harper, S. Sun, L. R. Dalton, S. Garner, W. H. Steier, Polymer Reprints Vol. 38, 1997.

13. "TM-pass Polarizer Based on a Photobleaching-Induced Waveguide in Polymers", Sang-Shin Lee, Sean Garner, Antao Chen, Vadim Chuyanov, William H. Steier, Seh-Won Ahn and Sang-Yung Shin, Photonic Technology

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16. “Patterned Birefringence By Photo-Induced Depoling in Electro-optic Polymers and Its Application to a Waveguide Polarization Splitter” Sang-Shin Lee*, Sean Garner, Antao Chen, Vadim Chuyanov, William H. Steier, Lan Guo, Larry R. Dalton, Sang-Yung Shin, accepted for publication in Applied Physics Letters
17. “Three dimensional integrated optics using polymers”, S. M. Garner, S-S. Lee, V. Chuyanov, A. Chen, A. Yacoubian, W. H. Steier, submitted to IEEE J. Quant. Electr.
18. “Recent advances in polymer electro-optic devices for photonics” (Invited), W. H. Steier, S-S Lee, S. Garner, A. Chen, H. Zhang, V. Chuyanov, H. R. Fetterman, A. Udupa, D. Bhattacharya, D. Chen, L. R. Dalton, submitted to J. Chemical Physics
19. “Vertically integrated waveguide polarization splitters using polymers” SGarner, V. Chuyanov, S-S Lee, A. Chen, W. H. Steier, L. R. Dalton, submitted to IEEE Phot. Tech. Lett.

Research Programs This Equipment has Assisted

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a. "Basic Materials and Fabrication Studies for Advanced Polymer Opto-electronics" F49620-94-1-0323 supported through AFOSR by Dr. Charles Y-C Lee.
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c. "An ASSERT Proposal for the Development of Advanced Polymeric Devices" F49620-95-1-0450, BMDO - AFOSR F49620-95-1-0445 under Dr. Charles Y-C Lee.
d. “RF Photonic Materials and Devices” N00014-97-1-0508 an ONR MURI Program under Dr. William Miceli
e. "Synthesis and Processing of New Second Order Nonlinear Optical Materials" F49620-94-1-0201, AFOSR under Dr. Charles Y-C Lee.
f. "Development and Ultilization of Device Quality Nonlinear Optical Materials" F49620-94-1-0312, AFOSR-BMDO under Dr. Charles Y-C Lee.
g. "An ASSERT Proposal for the Development of Advanced Polymeric E-O Materials" F49620-95-1-0450, BMDO - AFOSR under Dr. Charles Y-C Lee.
h. "MURI Program on Materials and Processing at the Nonometer Scale" F49620-95-NL-151, AFOSR under Dr. Charles Y-C Lee.